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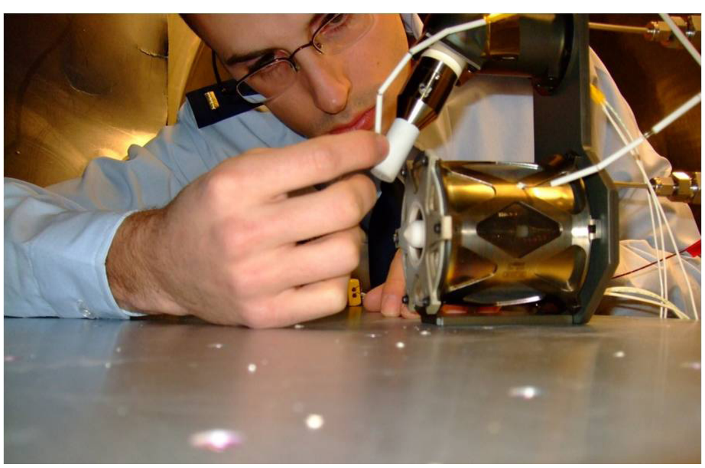
2015 Annual Report of the Graduate School of Engineering and Management, Air Force Institute of Technology

Office of Research and Sponsored Programs, Graduate School of Engineering and Management, AFIT

AIR FORCE INSTITUTE OF TECHNOLOGY

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT



2015 ANNUAL REPORT

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This Annual Report is published each year by AFIT's Office of Research and Sponsored Programs at Wright-Patterson Air Force Base, Ohio. It shares information about the activities of the Graduate School of Engineering and Management at AFIT with the Air Force, Department of Defense, and wider public. All images are Air Force, NASA, or AFIT owned or used with permission unless otherwise identified. The DOD, other Federal Government, and non-Government agencies supported the research reported herein but have not reviewed nor endorsed the contents of this publication.

The History of Icarus (cover photo)
In 1998, the AFIT Foundation initiated, commissioned, and funded, through contributions, the construction of a memorial to graduates of the Air Force Institute of Technology from the Air Force and Army Air Corps who lost their lives while in service to our country. Upon completion, the monument was offered as a gift to the Department of the Air Force and, under the provisions of Title 10, United States Code, Section 2601, accepted.

As the story goes, father and son were imprisoned together in the Labyrinth on the Isle of Crete, they escaped on wings fashioned by Daedalus from feathers and wax. But Icarus flew too close to the sun, the wax melted, and he fell to his death in the Aegean Sea as his father flew to freedom filled with sorrow for his loss. Though Icarus fell, he gained his freedom by daring to fly. The Icarus Memorial remembers the graduates of the Air Force Institute of Technology who gave their lives in service to our country.

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MESSAGE from the Dean

There is no place like the Air Force Institute of Technology (AFIT). Although we run an educational institution similar to many other institutions of higher learning, we are different and unique because of our defense-focused graduate-research-based academic programs. Our programs are designed to be relevant and responsive to national defense needs. Our programs are aligned with the prevailing priorities of the US Air Force and the US Department of Defense. This year, I will be celebrating my 10-year anniversary at AFIT. I am as excited today about AFIT as I was when I first came on board in October 2006. This is a point of pride for me, after serving in academic and administrative positions at two major civilian universities. One thing that is always foremost in my mind is the fact that, as a military organization, we have a special responsibility, not only to advance national defense, but also to contribute intellectually to the society at large. This is a unique opportunity for us to demonstrate our overall value to the nation.

Our latest strategic plan outlines the pathway for our continuous pursuit of excellence through superior teaching, research, and operational consultations. With our coordinated vision, we achieve excellence and with our unflinching pursuit of excellence, we achieve eminence in all we do. AFIT has provided advanced education to the Air Force and other military and government organizations for several decades. Our relentless efforts to push the boundaries of technology have led to patents and disclosures by teams of our faculty and students. All our accomplishments have been through focused teamwork and high-level external partnerships. Game-changer technologies, such as Hypersonics and Directed Energy, are in our portfolio of research engagements.

This year's report highlights the recent research achievements of our faculty and students, and features the outstanding work of our researchers in the fields of Additive Manufacturing and Nuclear Engineering. As we reflect on the accomplishments of 2015 with pride, the faculty, students, staff and I continue to work hard to align our core missions of education, research, and operational consultations. We are exploring new innovation in delivering our graduate education programs, leveraging our research pursuits to provide relevant and timely contributions to solve the pressing problems of today, and reaching out beyond the operational boundaries of the Air Force to address the needs of the society within which we live. We will continuously strive toward our vision of excellence in defense-focused, research-based advanced STEM education to better serve our students, the United States Air Force, and our nation. I invite you to join us in this teamwork effort.

With the best AFIT regards to all,
Adedeji B. Badiru, Ph.D., PE
Dean, Graduate School of Engineering and Management
Air Force Institute of Technology

RESEARCH SPOTLIGHT
Additive Manufacturing

Additive Manufacturing Improves Operational Support

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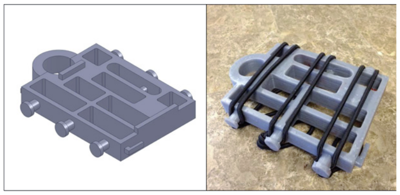
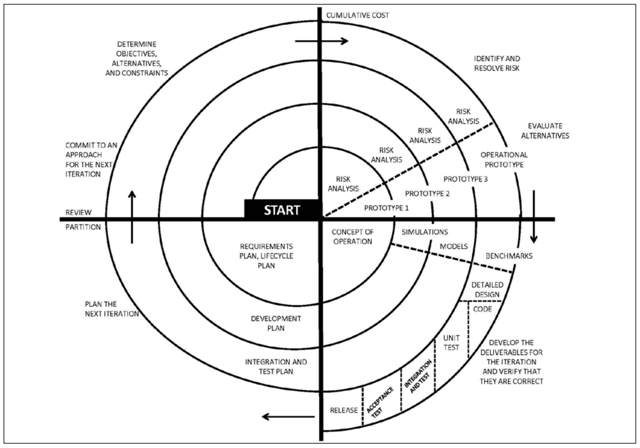
Explosive Ordnance Disposal (EOD) technicians at Wright Patterson AFB's 88th Air Base Wing collaborated with students from AFIT's Engineering Management program to solve an operational problem through additive manufacturing. EOD technicians often utilize an unmanned ground vehicle (UGV) (i.e. EOD robot) to carry a variety of biological, chemical and explosive sensors into hazardous areas. Although the UGV has a standard mount to carry up to a 300-pound piece of equipment, the sensors employed in many EOD responses come from different base agencies and weigh no more than four pounds. As such, these sensors have varying shapes and sizes and cannot be directly mounted using the UGV's standard mounting point. Instead, an EOD technician's standard operating procedure calls for using off-the-shelf "duct tape" to attach these sensors to the robot. While this is a convenient and immediate fix, this solution actually requires more labor after the operation in removing the tape and cleaning the sticky residue.



Sensor Bracket Digital Design (left)
Final Prototype (right)

As a course project, students at AFIT developed a plastic sensor bracket specifically for EOD's small sensor use case. Additive manufacturing's strength was leveraged for this problem; 3-D printing machines have the ability to print one-of-a-kind parts at low volume. For the project, students designed the bracket specifically to hold the uniquely shaped sensors and to attach directly to the UGV's mounting point.

The students also demonstrated additive manufacturing's agile production cycle. Using the systems engineering spiral process model, students conducted requirements analyses, generated alternatives and tested three different prototype designs within a ten-week course period. At the conclusion of the course and with the help of the 788th Explosive Ordnance Disposal Flight, the students field tested the completed bracket with promising results.



Systems Engineering Spiral Process Model

This research demonstrated that additive manufacturing can be used today to improve operations for EOD units by providing a means to procure unique, one-of-a-kind parts. If a low volume of these parts are required and notwithstanding the material limitations of plastics, commercially available off-the-shelf additive manufacturing machines can be a cost-effective parts procurement method for operational units. Airmen across the Air Force could then employ this technology, along with file sharing of digital designs, to collaborate with each other on solutions to other real-world and in-the-field problems. This research is a proof-of-concept that additive manufacturing can provide operational support to the many unique and varied challenges faced by today's Air Force.

Airman from the 788th EOD Flight tests the prototype bracket attached to the UGV.

Computer Simulation of Multiscale Adaptive Deposition

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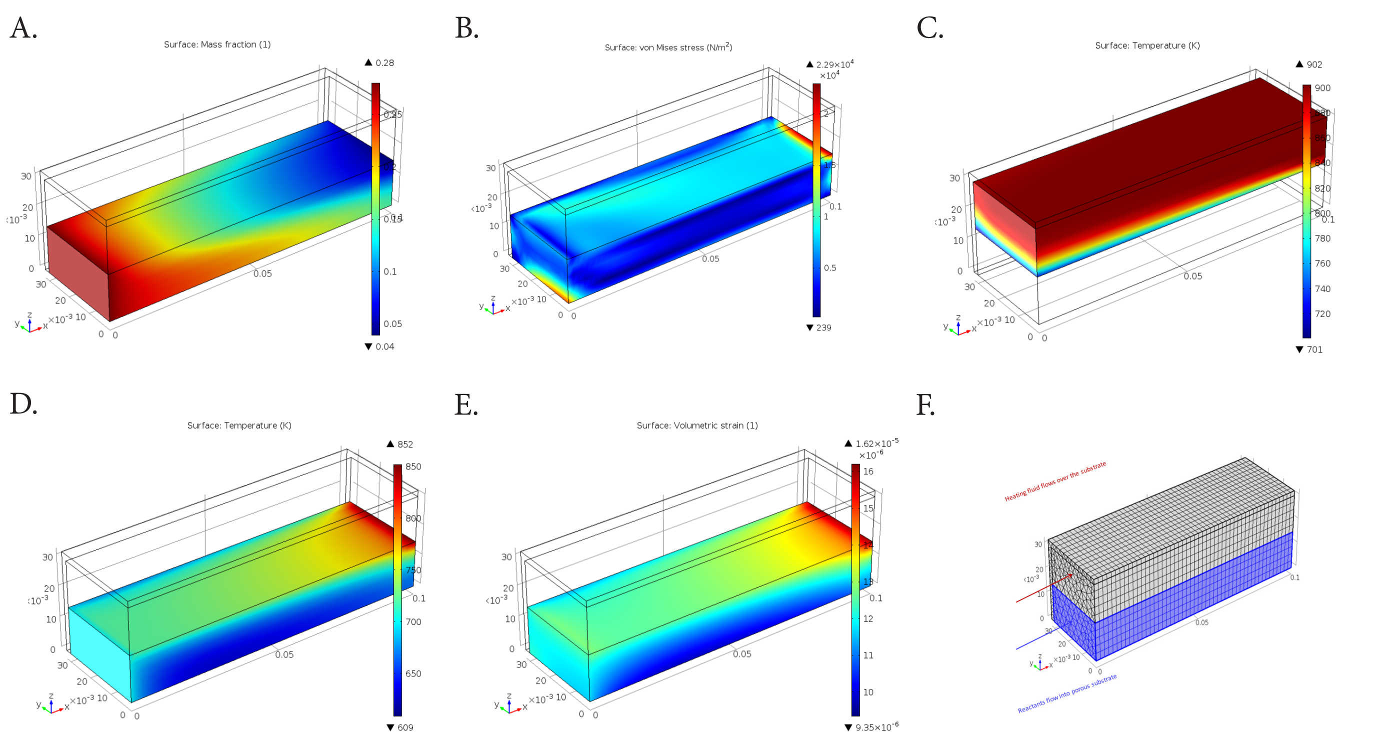
AFIT is exploring the use of computer simulation to gain insight into some important additive manufacturing parameters that are usually difficult to obtain by means of experiment. Multiple depositions of preceramic polymers are usually required to achieve acceptable properties and performances for advanced composite materials. The deposition process involves several physical and chemical phenomena such as fluid flow, diffusion and reaction. Traditional methods produce films /coatings by repeating the deposition process multiple times, using the same precursor solution. The substrate structures and properties (the pore size, surface wettability and the substrated permeability) may change when loaded with the infiltrated polymers.

Such changes may have a great impact on diffusion, reaction and thermal transport in the successive filler material; which in turn can significantly affect interfacial strength of multi layer structures. An experimental investigation of the wide range of parameters is time consuming and cost prohibitive, making computer simulation desirable.

Our computer simulation focuses upon fluid flow, energy balance in thermally-activated chemical reactions, heat and mass transport and thermo-mechanical stress in the porous structure. A snapshot of the computer simulation results is illustrated in the figure.



Finite element analysis (FEA) simulation of steady-state distributions of chemical concentration temperature, stress and strain for a model material system under hypothetical experimental conditions.

RESEARCH SPOTLIGHT

Additive Manufacturing

AFIT Applies 3D Printing to Advanced MEMS Research

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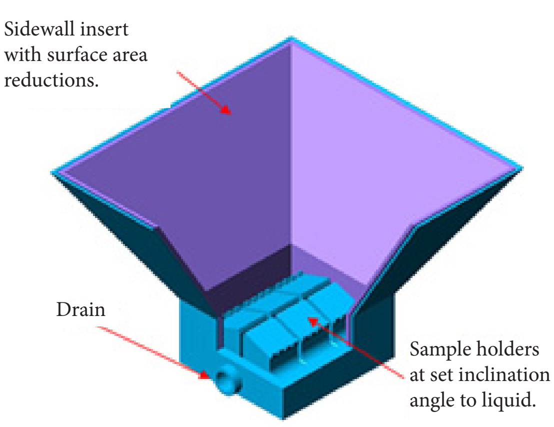
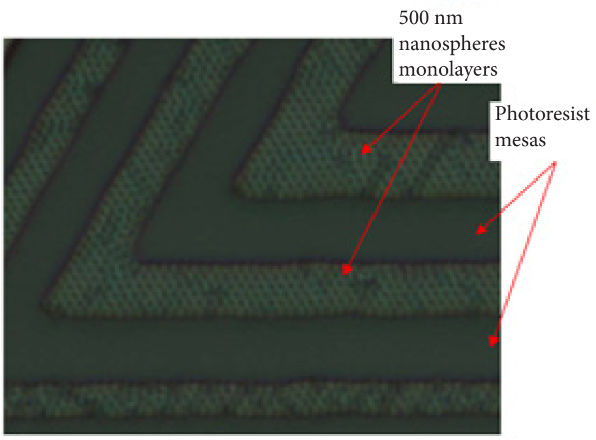
3D printing has been used for a wide variety of applications since its invention over a decade ago. In the medical industry, construction and manufacturing, this technology has advanced beyond a research interest and is being used in the field as a practical, viable technology. This in turn, has led to the marketing of relatively inexpensive, commercially available 3D printers. The popularity of these systems is the driving force behind the constant improvements and these systems are now capable enough to be used in aiding research in fabricating Microelectomechanical Systems (MEMS). Maj Tod Laurvick in the Department of Electrical and Computer Engineering, has applied this technology to address reproducibility challenges in using nano-scale spheres as a part of device fabrication.

Nanospheres are of particular interest in MEMS fabrication, in part because they allow the means to pattern features that are too small to realize effectively with other techniques. For example, optical based lithography has fundamental size limitations due to diffraction; and other approaches, such as electron beam lithography or etching using a focused ion beam, present cost, fabrication time and other issues.

While decades of research on self-assembled layers of nanospheres show their potential for cost effective fabrication of small features, achieving repeatable results remains challenging. This is primarily because a number of physical parameters related to the test setup (e.g. the relative angle of the liquid surface to the substrate on which patterning occurs, the rate at which the fluid is removed and the change in surface area during deposition) are difficult to control and greatly affect the results. 3D printing provides a potential solution, since it allows for fabricating, testing and refining specialized nanosphere depositon vessels (see figure) to develop process control approaches quickly and at nominal cost.

So far, the best AFIT results show roughly an order of magnitude improvement in patterned surface area when compared to the best results found in the literature. While these results are adequate to proceed with current research, further improvement may be possible through other applications of 3D printing to aid in precise flow control of the carrier fluid. The intent is to use these results in conjunction with other, more traditional patterning techniques to provide a method to precisely control small groups of nanospheres in specific locations. These can then be used along with other fabrication steps to provide a new level of feature resolution in MEMS fabrication.





Deposition vessel (left) and resulting positioned monolayers achieved (right).

Optical Diagnostics for Metal Additive Manufacturing

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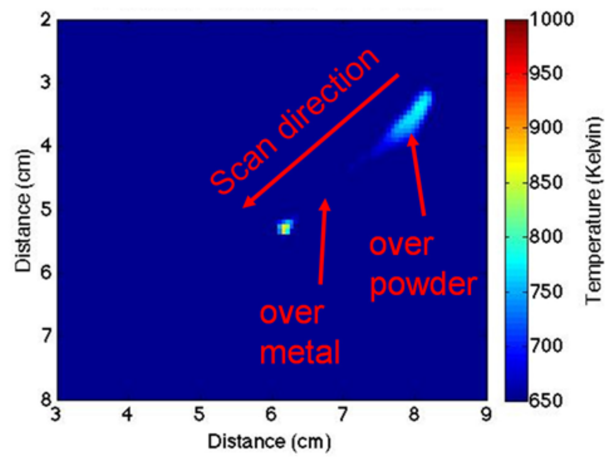
Metal Additive Manufacturing (AM) is emerging as a viable commercial manufacturing technology for the production of mechanical parts from three dimensional model data. To ensure the fabricated parts meet production standards, methods for non-destructive inspection and real-time process control are needed to assess the physical characteristics of deposited material as it is formed and before it is encased in an inaccessible location within the part.

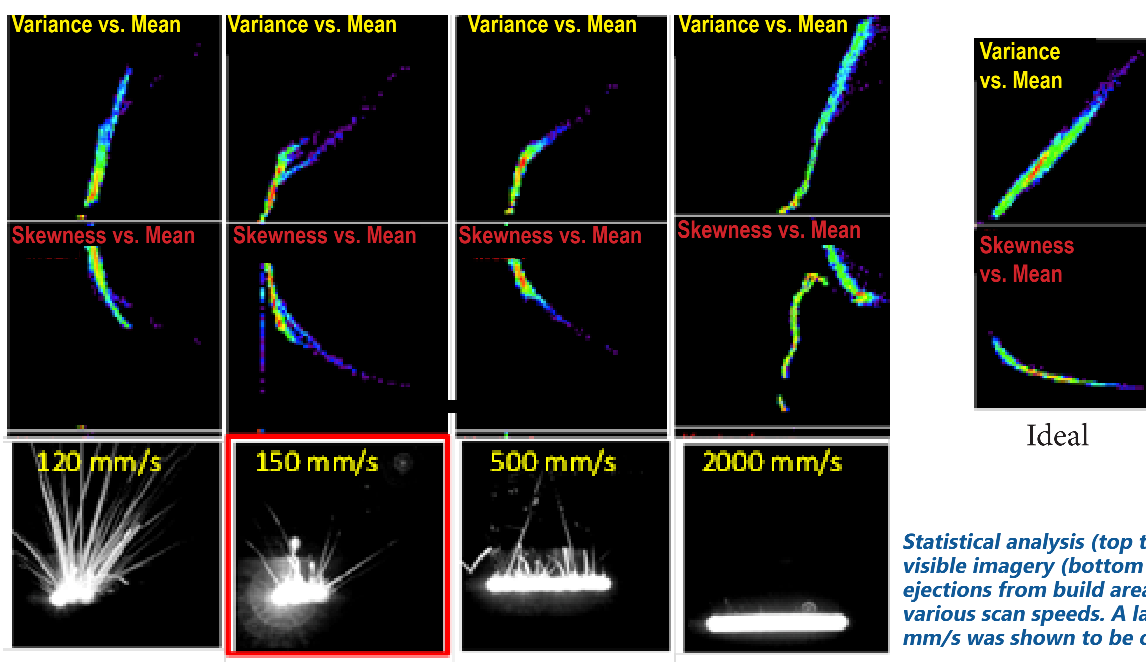
Dr. Glen Perram is leading AFIT's Engineering Physics faculty and students in a NASA sponsored STTR Phase II collaboration with Mound Laser & Photonics Center (MLPC), a Dayton, Ohio small business, to develop optical diagnostics for *in situ,* on-line monitoring of Selective Laser Melting (SLM) AM. AFIT researchers have used mid-wave, infrared imagery to monitor material surface temperatures and track thermal diffusion characteristics of titanium alloy (Ti64) melt pools in MLPC's SLM prototype system. Surface temperature maps were shown to provide a signature that is sensitive to laser power, oxygen content, powder size and sub-layer structure.

In addition, AFIT researchers employed high-speed, visible imagery (>10,000 frames per second) to record the intense sparking behavior often observed during SLM. Small explosive events producing ejected particles were observed during laser heating of the build area. Statistical metrics have been calculated for the spatial distributions of ejected particles at various laser scan-speeds, a critical build parameter.

Future work includes correlation of the above sensor data with microstructure characteristics of fabricated parts, exploration of visible and infrared spectroscopic signatures and optical sensor investigations of electron-beam AM processes.



Instantaneous thermal imagery captured during the laser melting of Ti64 powder. The thermal diffusion rate is not noticeably slower for a sub-layer of powder.



Statistical analysis (top two rows) of high-speed visible imagery (bottom row) showing particle ejections from build area during laser melting of various scan speeds. A laser scan speed of 150 mm/s was shown to be optimal.

RESEARCH SPOTLIGHT
Nuclear Engineering

Calculating Radiation Protection Factors for Modern Combat Vehicles

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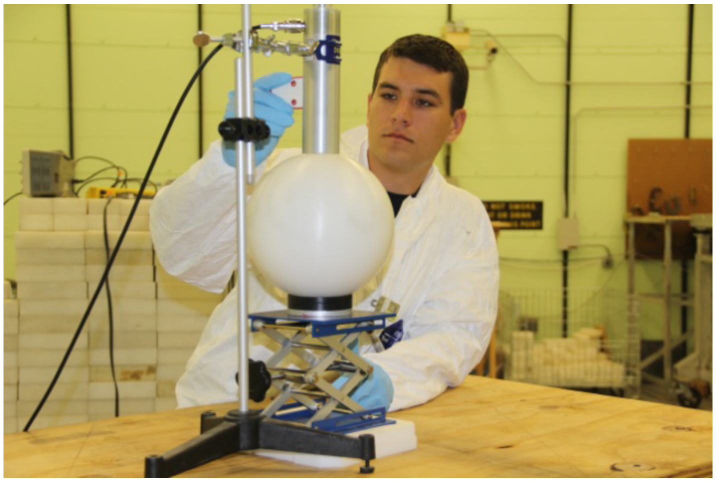
In the past, the U.S. Army routinely conducted experimental and computational assessments of mission critical vehicles to determine the degree of radiological protection each afforded the crew. For modern combat vehicles, this information does not exist and the techniques employed in the past to acquire such data have atrophied. To restore this capability, the Department of Defense and the Defense Threat Reduction Agency (DTRA) identified computational methods as the optimal means to determine the Radiation Protection Factor (RPF) of each modern system, specifically through utilizing the Los Alamos National Lab Monte Carlo n-Particle code (MCNP).

Representing a simplified military vehicle, a steel box is modeled in MCNP and exposed to a simulated ^{235}U neutron fission spectrum; the perturbed neutron energy spectrum is recorded at the center of the box. This simulation is repeated without the steel box to compute the free-field neutron flux and a neutron protection factor (NPF) is then calculated from the MCNP-derived flux data. This computational design is then repeated as a physical experiment using the White Sands Missile Range Fast-Burst Reactor as the ^{235}U neutron fission source. Final NPF values differed by less than five percent, so the experiment further supports the verification and validation of MCNP for the



A midshipman AFIT intern from the Naval Academy provides a view of the Bonner Sphere Spectrometer (BSS) employed in the free-field measurement configuration.

eventual purpose of estimating the NPF of current military vehicles for the U.S. Army. AFIT nuclear engineering student, Capt William Erwin and faculty, Dr. Justin Clinton and Dr. John McClory, developed and ran the simulation; and planned and conducted the experiments at the Fast Burst Reactor.

Despite the strength of these results, the challenge inherent in validating MCNP for RPF assessments of military vehicles remains both complex and lengthy. Although the results of this research provide further support for the reliability of MCNP-derived NPF estimates, future research must still occur before the code is approved by the DOD for use in determining official RPF estimates of U.S. military vehicles. Specifically, the simplistic experimental design incorporated in this study precludes the application of these results to problems with increasingly complex geometries and materials. Therefore, subsequent experimental designs used in DTRA RPF research will incorporate both simplistic and composite material layering, as well as more complicated geometries.

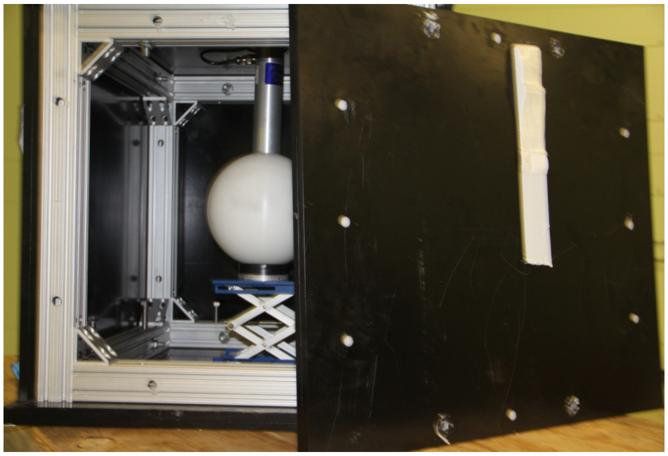


Image of the experimental set up using the BSS. This demonstrates the orientation of the BSS after insertion into the steel box.

Analyzing Materials for Future Clean Nuclear energy

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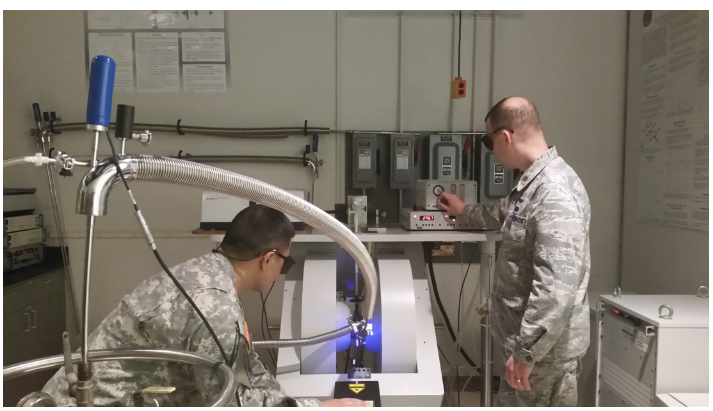
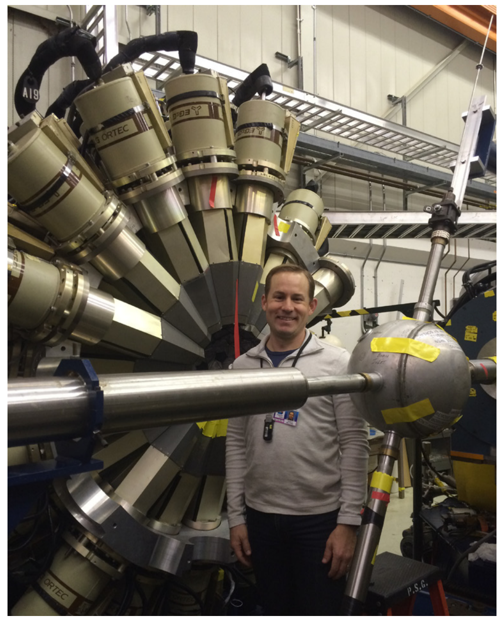
Army CPT Shamaun Holston is investigating how lithium aluminate ($LiAlO_2$) behaves in a nuclear reactor environment for a research project sponsored by the Defense Threat Reduction Agency. $LiAlO_2$ is used to produce tritium, which is a core fuel used in nuclear fusion. The production of hundreds of kilograms of tritium will be vital if the United States ever plans to have large scale fusion power plants. The United States produces tritium by bombarding lithium aluminate rods with neutrons at the Tennessee Valley Authority (TVA) Watts Bar 1 Nuclear Reactor and then extracts the tritium from the rods at the Savannah River Site Tritium Extraction Facility.

Nuclear reactors emit x-rays, high-energy electrons, and neutrons changing the optical, chemical, and electrical properties of $LiAlO_2$ in ways that are not well understood. For example, tritium leaks out of the $LiAlO_2$ rods at more than 4 times the expected rate, for reasons that remain unknown. This significantly hampers the United States' ability to produce tritium. By studying the properties of $LiAlO_2$ in experimental environments that contain x-rays, high-energy electrons, and neutrons, CPT Holston will be able to determine the effects of radiation on these properties of $LiAlO_2$ by measuring how the samples absorb light, how they behave under temperature changes and by probing their nuclear structure using magnetic resonance techniques.



AFIT professor, Maj Eric Golden, and AFIT student, Maj Ember Maniego, work with the EPR spectrometer in AFIT's Materials Characterization Laboratory.



AFIT student Maj David Matters, in the Gammasphere facility at Argonne National Laboratory's Atlas Accelerator.

CPT Holston has identified the major electronic structure changes in $LiAlO_2$ that arise from x-ray radiation and characterized how the changes affect optical and electrical properties. Ongoing research will potentially identify and explain similar changes that arise from high-energy electron and neutron radiation and likewise determine how they affect material properties. Ultimately, we hope to understand how these radiation-induced defects interact with tritium inside $LiAlO_2$, which could provide solutions to issues such as tritium leaks from $LiAlO_2$ reactor rods.

Simulating Electromagnetic Pulse at Air Burst Altitude

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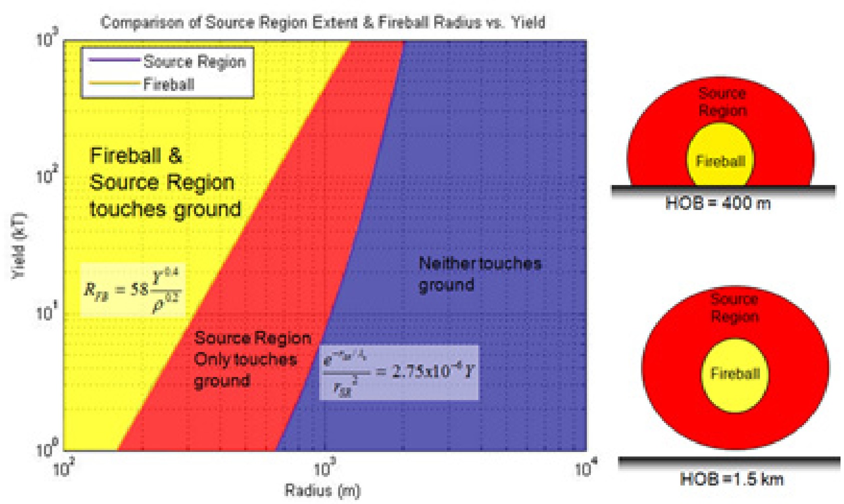
Electromagnetic Pulse (EMP) generated from a nuclear weapon detonation has been studied since the United States ceased atmospheric testing in 1962. Exo-atmospheric and ground burst predicting EMP from air bursts were not previously developed. Modeling EMP from air bursts requires dissimilar techniques to those employed in high altitude or ground burst models due to the difference in the physical processes generating the EMP. The Air Force Nuclear Weapons Center requires the capability to simulate EMP from air bursts to facilitate aircraft safe escape studies which supports U.S. Strategic Command's nuclear planning. AFIT researchers are investigating new models to address this need.

This research proposed a new term, Air Burst EMP (ABEMP), which serves to codify the region of interest that requires a special treatment of the Compton current and asymmetry that must be considered in calculation of the EMP. The concept of ABEMP was considered in the B-code, written in 1967. The initial code was written in FORTRAN IV and in the present research was rewritten in MATLAB and modified to include modern methods of calculation and provide better accuracy. After initial verification of code output, the adequacy of the B-code air conductivity model was investigated through a comparison with DCHEM, a 53-species reaction rate air chemistry code.

The results indicate that adding a water vapor dependency to the lumped parameter electron attachment rate and electron-ion recombination rate at the lower altitudes of the air burst domain provides a better estimate of the air conductivity without modeling all ionic species. This addition adds a minimal increase in computation time. Additionally, this research demonstrated differences between the predicted EMP waveform using a ground burst or exo-atmospheric model when applied to an air burst. Finally, the B-code results provided insight into the propagation direction of the maximum electric fields from the air asymmetry, which differed significantly from simplistic renditions of ABEM detonations in the literature.



The region in red shows that the radius for an EMP source region will always be larger (at any weapon yield) than the fireball (region in yellow) and therefore the definition of an ABEMP must be when the EMP source region doesn't intersect the group. In other words, the ABEMP region of interest will begin at a higher altitude than the standard air burst definition of the nuclear fireball not intersecting the ground.

Y=Yield of Weapon in kilotrons
HOB = Height of Burst
rho = Atmospheric Density
Lambda = Mean free path of photons in air
R_fb = Radius of Nuclear Fireball
R_sr = Radius of EMP Source Region

Solid-State Radiation Detection using Uranium Dioxide Crystals

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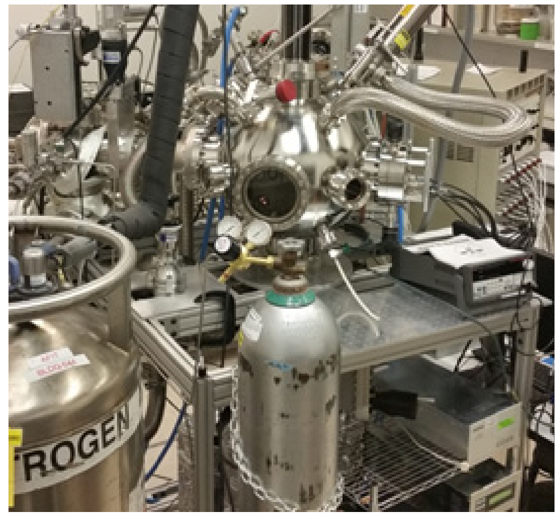
Neutron detection is an integral part of our government's efforts to detect the illicit trafficking of special nuclear materials. The bulk of the detection burden has traditionally been provided by systems equipped with ^{3}He because of many highly desirable properties; including a high neutron capture cross section. However, due to the dramatic increase in the use of this gas, combined with a dwindling supply, there is a critical shortage of gas for use in detectors. The gas could be purchased for slightly more than $100 per liter in 2009, but is now commanding a price in excess of $2,100. Alternative neutron detection materials are being sought that could provide reliable, low-cost, low energy methods for neutron detection.

AFIT's research approach to the ^{3}He shortage has been in the development and analysis of solid state crystals made of UO_2 that can replace ^{3}He detectors. The UO_2 has several advantages including: reduced size and weight, lower background interference from gammas, and if successful, the possibility of energy analysis of the neutron source. Uranium is well known for its use in nuclear reactors and the neutron reactions are well-characterized. However, the use of UO_2 to fabricate an electronic sensor has never been done.

The research is being conducted in collaboration with Air Force Research Laboratory/Optoelectronic Technology Branch (AFRL/RYDH) where hydrothermal processes developed by Dr. Matt Mann have provided neutron detection materials of sufficient quality to begin analysis of the detection efficiency. The crystals are first analyzed using a variety of spectroscopy methods developed specifically for this type of research in one of the Department of Engineering Physics' high-technology laboratories. Then, the crystals are placed into a specially developed holder and bombarded with various radiation sources. Since such materials have never been used in this way, analysis of the electronic noise and output signals have proven a challenge, and require a substantial post processing routine. It is the current objective of the research team to determine how to separate the various interactions in the UO_2 crystal.



AFIT laboratory for Uranium Dioxide Research

This AFIT/AFRL research has brought the DOD one step closer to the reality of a solid-state neutron detector. AFIT research continues in parallel with the detector work to develop a deeper understanding of the electronic properties of UO_2 in order to produce more efficient detectors.

If you would like more information about how to sponsor a thesis or about AFIT's Additive Manufacturing and Nuclear Engineering Programs please contact:

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RESEARCH
Highlights

New iOS App for Aeromedical Evacuation Planning in Development

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A challenging factor during Aeromedical Evacuation (AE) is patient positioning on the aircraft. Driving factors in this process are: patient type (litter or ambulatory), patient injury/illness, patient acuity and patient destination. Prior to each mission, an AE crewmember designs a patient positioning plan with consideration of the aforementioned factors. Utilizing their clinical and flight expertise, this individual assigns each patient a litter location or seat (in the case of ambulatory patients). Additionally, this patient positioning plan also includes seat assignments for the flight crew, AE crew and non-medical attendees. In current operations, this process is completed utilizing a spreadsheet and may have to be repeated multiple times, by hand, due to changing patient status or mission delays. This paper-based plan is distributed to the AE crew (by hand) and to the Contingency Aeromedical Staging Facility (CASF) and United States Transport Command (USTRANSCOM) (via email of scanned copy).

Due to the dynamic nature of the AE mission planning process, a user-friendly, interactive tool to aid AE personnel in the development of patient positioning plans would streamline the mission planning process by reducing the time required to create and distribute the patient positioning plan. Additional recommendations based on pre-programmed patient positioning guidelines, could also assist AE personnel in developing individualized patient plans depending on their patient's medical status. Standard checks could be incorporated to assist the patient positioning plan creator and may improve patient safety and/or pain management by ensuring the patient is placed in an optimal position for his/her condition.

Under the guidance of Dr. Raymond Hill, researchers in the Center for Operational Analysis (COA) have collaborated with the 711th Human Performance Wing (HPW) to demonstrate a proof of concept (POC) for a computer based patient positioning plan tool for AE personnel. This POC is currently in the form of an iOS app and allows individuals to select one of three airframes: C-17, C-130 and KC-135. Once the user selects the airframe of choice, a list of preloaded patient names appear. Users are able to select the patient of choice and drag and drop the patient to their desired location. Users are also able to select from a list of standard equipment and other individuals on the flight, such as the AE crew, flight crew and non-medical attendees. Once the patient positioning plan is complete, the user can save the plan and distribute as necessary.

Future efforts may include: algorithm development for incorporating checks based on patient positioning guidelines, investigating the feasibility of combining this assistive tool with the Electronic Flight Bags used by AE personnel, integrating patient information into the patient positioning plan tool before flight, enhancing the dissemination capabilities of the patient position plan and usability testing with AE personnel and other subject matter experts. While the initial POC has been developed, further research is needed to enhance the capabilities of the patient positioning planning tool to streamline the mission planning process and assist AE personnel in ensuring patients are placed in the optimal location based on his/her needs.

Defense.gov. Defense.gov News Photos. [Online] May 30, 2011. [Cited: November 19, 2015.] http://archive.defense.gov/photos/newsphoto.aspx?newsphotoid=14522.

CWMD Student Combats Dengue Virus

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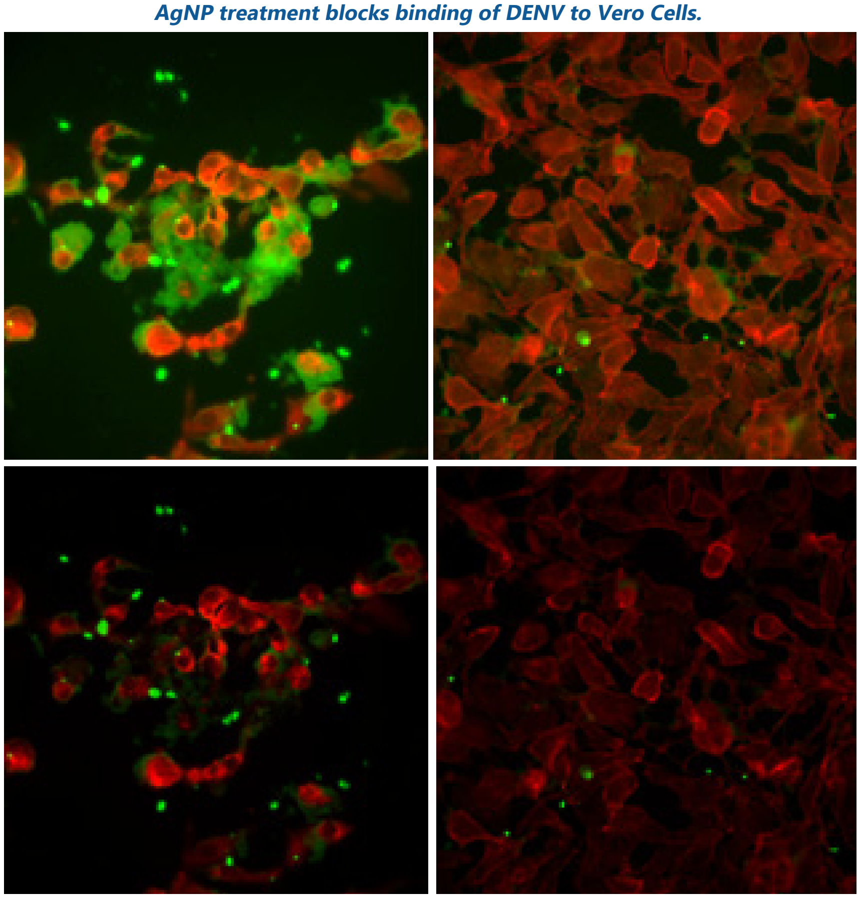
CPT Kelly Williams, a recent graduate from the Combating Weapons of Mass Destruction Program, in collaboration with Dr. Saber Hussain (711th HPW) demonstrated the first inhibition of a class IV virus using silver nanoparticles.

Dengue Virus, also known as Break Bone Fever, is a hemorrhagic fever virus and is considered one of the most important arboviruses in the world, infecting between 50-400 million persons per year. Several different strains of the virus exist in nature, making an effective vaccine particularly difficult to develop. As a result, there are currently no medical countermeasures available for the Dengue infections.

Silver nanoparticles have proven effective in preventing viral infections. However, to date, silver nanoparticles have not been tested against single strand (+) RNA viruses (class IV). In this research, Dengue virons were incubated with silver nanoparticles prior to exposure to a target culture. The cells were then assayed for the ability of the Dengue to bind to the target cells.

Fluorescent images of cells exposed to treated Dengue Virus demonstrated a 92-96% reduction in virus binding when compared to cells exposed to the un-treated virus. While the exact inhibition event was not determined, this is the first reported instance of silver nanoparticles showing anti-viral properties against a class IV virus. Future research will focus on identifying the particular physical action preventing virus binding and infection, which could lead to advances in medical treatments and WMD countermeasures.

AgNP treatment blocks binding of DENV to Vero Cells.



(A) DENV binding to Vero cells without AgNP treatment. Image brightness and contrast enhanced 40% for better viewing in print

(B) DENV binding inhibited by pre-treatment with AgNP (25µg/mL). Green fluorescence (FITC, DENV E protein) and red fluorescence (TRITC, f-actin). Image brightness and contrast enhanced 40% for better viewing in print.

(C) Non-enhanced composites.

(D) Non-enhanced composites.

Fast Hyperspectral Imaging for Per-Pixel Classification of Brief Events

Maj Dustin Mixon • Dustin.Mixon@afit.edu • 937-255-3636 x4516

In July 2013, the National Science Foundation, in partnership with the Defense Threat Reduction Agency and National Geospatial-Intelligence Agency, awarded a three-year grant of $1 million to AFIT and the University of Missouri-Columbia, to produce new algorithms for automatic threat detection. As part of this research, AFIT faculty and students in the Department of Mathematics and Statistics leveraged techniques from an emerging field known as compressed sensing, to enable the hyperspectral imaging of brief and spatially localized events.

A hyperspectral image is a cube of data; each slice corresponding to an image of a common scene in a fixed wavelength of light (see Figure 1). Standard color images use only three slices from the hyperspectral image cube (namely, these slices corresponding to red, green and blue wavelengths). By acquiring slices from hundreds of additional wavelengths, the chemical composition of each spatial pixel in the image can be determined. Indeed, while an apple cannot be distinguished from a fire hydrant by the shades of red they exhibit, the difference can easily be discerned after considering wavelengths that are imperceptible to the human eye.

Traditional hyperspectral imaging requires the number of exposures to scale poorly with the spatial resolution of the desired images; and this large number of exposures limits the temporal resolution available. To address this shortcoming, the AFIT team, consisting of faculty members Dr. Matthew Fickus, Major Dustin Mixon, and Captain Jesse Peterson, along with master's student Second Lieutenant Megan Lewis, developed new coded apertures for hyperspectral imaging with a micro-mirror array model (see Figure 2). In the case where the scene of interest is spatially localized, one only needs a few exposures to determine the entire scene. This low-exposure capability allows one to image rapidly evolving scenes. These results made up a large portion of 2d Lt Lewis' master's thesis, which was recognized with the 2015 Chancellor's Award - the highest AFIT award for Master's-level research.

Figure 1: Data cube of hyperspectral imagery. Each slice images the intensity of light in a fixed wavelength. One may discern the chemical composition of a pixel (e.g. water, foliage, rock) from how the light intensity varies with wavelength. (From N. M. Short, Two-dimensional projection of a hyperspectral cube, 2013.)

Having developed techniques for acquiring hyperspectral data with improved resolution, the AFIT team is now concentrating on the classification portion of the project. For this portion, the team will devise new techniques and performance guarantees for the clustering and classification of hyperspectral signatures.

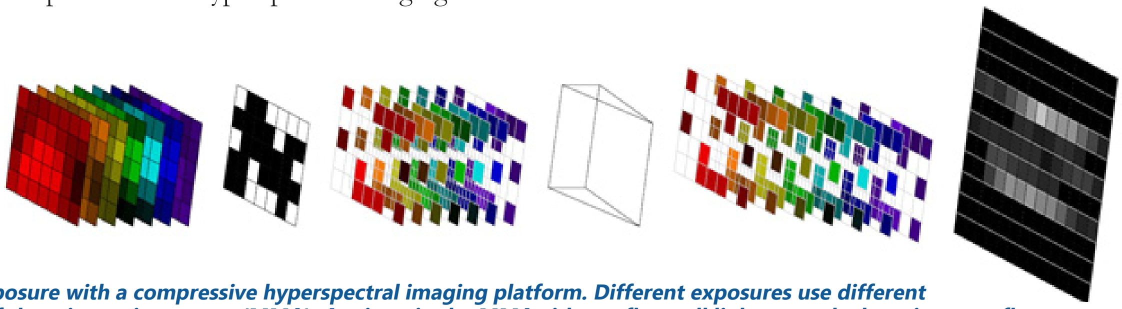


Figure 2: One exposure with a compressive hyperspectral imaging platform. Different exposures use different configurations of the micro-mirror array (MMA). A mirror in the MMA either reflects all light towards the prism or reflects all light away from the prism. After the light is dispersed by the prism, it is collected on a charge-coupled device. (From M. Fickus, M. E. Lewis, D. G. Mixon, J. Peterson, "Comprehensive Hyperspectral Imaging for Stellar Spectroscopy", IEEE Signal Processing Letters 22 (2015) 1829-1833.)

Advancing Cost-Effective Readiness by Improving Supply Chain Management of Sparse, Intermittently-Demanded Parts

Dr. Jeffery Weir • Jeffery.Weir@afit.edu • 937-255-3636 x4523

Under the direction of Dr. Jeffery Weir, Director of Research in the Center for Operational Analysis, Ph.D. student Dr. Greg Gehret recently finished his dissertation analyzing different ways of optimizing supply chain management strategies to reduce time to repair and total cost of operating United States Air Force (USAF) aircraft. There were two main focuses of this study which aimed to improve stock policy on sparse intermittently demanded items and develop a framework for forward looking metrics for supply chain managers. Inexpensive parts were broken down into a two tiered parameter stocking policy for cost for each different number of locations for stocking parts. This allows decision makers to choose

http://mediaassets.reporternews.com/photo/2014/05/29/20100422-143901-pic-608600442_5393578_ver1.0_640_480.jpg

how many different locations to have for parts, given their budget constraints. Preliminary analysis concluded the possibility of reducing the supply chain cost by more than $7M on the A-10C fleet and can be extracted to other Air Force fleets.

Expensive and repairable parts used multiple objective optimization where parts were broken into two groups of six, based on the total cost to replace broken items. A multiple regression metamodel for customer wait time and inventory dollars was created and applied to the B-1 bomber for a case study. When applied to the B-1 fleet, it was concluded that by optimizing the supply chain, approximately $20M less inventory can be on

SSgt Mathew Johnson, 7th Equipment Maintenance Squadron, places a hose into a hydraulic fluid holding tank while servicing a B-1 Bomber May 16, 2013, at Dyess Air Force Base, Texas. While being serviced, more than 215 panels are removed and every component of the aircraft is inspected. (U.S. Air Force photo/Tech. Sgt. Joshua T Jasper)

hand with no increase in customer wait time. This methodology can likely be exportable to other Air Force fleets as well.

A forward looking risk model was developed to suit the needs of Air Force Research Laboratory's task to support the "Complex of the Future" program to provide a strategic vison and roadmap for modernizing the makeup of the three sustainment Depots in the next 20 years. The framework developed by Dr. Gehret is being considered for implementation in the "100% Parts Availability" initiative and is using the reliability block diagram among other models, to get insights on process integration and parts available.

If you would like more information about how to sponsor a thesis or about the Center for Operational Analysis, please contact:
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RESEARCH
Highlights

Supercomputing with Systems Tool Kit (STK) for Complex Systems Trade Studies

Lt Col Thomas Ford • Thomas.Ford@afit.edu • 937-255-3636 x4747

Although AFIT embarks on many research efforts in response to the needs of a single Department of Defense (DOD) sponsor, sometimes a ground-breaking project has the potential to simultaneously enable the research efforts of many DOD organizations. Just such a project was undertaken this year as a joint venture between AFIT's Center for Space Research and Assurance (CSRA), AFIT's Department of Systems Engineering and Management, the DOD Supercomputing Resource Center (DSRC) and Analytical Graphics, Inc. (AGI).

The former Director of CSRA, Colonel Matthew Sambora, USAF, Retired had a vision for creating a supercomputing capability which would enable large scale evaluation of complex multi-domain architectures in response to many DOD research needs. Lieutenant Colonel Thomas Ford (Assistant Professor of Systems Engineering) and "Python" David Meyer (Applied Research Solutions, Inc.) took Col Smabora's vision and turned it into a reality. This interest precipitated the successful porting and installation of AGI's ubiquitous Systems Tool Kit (STK) software onto a DOD supercomputer. STK is a time-dynamic, physics-based geometry engine which enables modeling, simulation and analysis across land, sea, air and space domains. STK also provides a trade space analysis capability for performing course of action assessments, resiliency analysis and overall decision support throughout the program lifecycle and across the engineering "V". Currently, STK has 50,000 registered instillations at over 700 academic, government and industry organizations.

Whereas faculty and students at AFIT previously spent hours, days and even weeks to run a complex simulation of satellites, unmanned aerial vehicles and surface systems; this integration shatters the run-time glass ceiling by allowing us to run STK on 22 supercomputing compute nodes simultaneously. This will allow AFIT faculty and students to run future large scale analysis trades spanning multiple domains and will drastically increase the number and complexity of systems architectures which can be assessed. Lt Col Ford and Mr. Meyer see this year's efforts as just the beginning; with this new supercomputing capability, AFIT hopes to support the research needs of many DOD organizations and to be able to share the new analysis capability they have developed with any DOD organization who desires it. Over the coming year, AFIT will continue to develop this capability and work closely with AGI and the DSRC to ensure the latest, most capable version of STK is available to supercomputing customers across the DOD.

Cost Capability Analysis

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In speaking at the Defense Industrial Policy Series, Secretary of the Air Force Deborah Lee James said, "...no matter how the Air Force is funded - it's clear that one of our mandates is to steward the taxpayer's dollars the best way we can." She went on to share that the Air Force is instituting a Cost Capability Analysis (CCA) program as a part of its endeavors to achieve that mandate. CCA is focused on better articulating a program's operational needs in terms of gaps in capability, as opposed to performance attributes and in turn, maximizing that capability while minimizing the program's costs.

The Center for Operational Analysis, in conjunction with Air Force Material Command Headquarters/A5 and Air Force Life Cycle Management Center Operations Research and Analysis Division, designed three levels of training to support the implementation of CCA. These include: a gen eral overview for senior leaders on the goals of CCA and the methods used in its implementation, a detailed course for program managers and their staff to prepare them for the actual execution of the CCA process when they have a program entering the acquisition phase and a formal certification program for analysts who will be facilitating the CCA. The training is intended to provide an appropriate amount of detail regarding the modified multi-objective decision analysis approach being used in CCA, as well as highlight the benefits that a structured decision analysis process can provide.

This training will result in a better understanding of CCA and will allow those involved in future acquisition efforts to be better prepared to evaluate capability requirements while assessing crucial operational trade-offs. This will hopefully lead the Air Force to higher fidelity acquisition decisions in an era of expanding requirements and shrinking budgets.

RESEARCH
Highlights

Meteorology Program becomes AFIT's Atmospheric Science MS Program

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In response to the 2011 request of the Director of Air Force Weather, the Department of Engineering and Physics (ENP) implemented a 21-month MS program, Atmospheric and Space Sciences that integrated the studies of the air and space environments. The new MS track started in 2012 with the concurrent arrival of new faculty and students. By 2014, the students completed multiple research projects that were on target to solve some of the Air Force Weather's top operational problems such as; verifying the accuracy of the new weather ensemble models, Using dual pole radar data to forecast the onset of lightning at the Kennedy Space Center, FL, Using high resolution weather models to forecast thunderstorm onset at Eglin AFB, Using remote sensing to determine cloud base heights in data sparse regions and Forecasting helicopter brown out conditions.

In the spring of 2014, the new Director of Air Force Weather, pleased with the student research successes thus far, asked if AFIT could re-activate an 18-month MS weather program that could handle double the number of students and tackle a greater number of the annually expanding operational research problems. AFIT and the Director of Weather signed an MOA later that summer addressing the program resource requirements, and the new Atmospheric Sciences MS program development began.

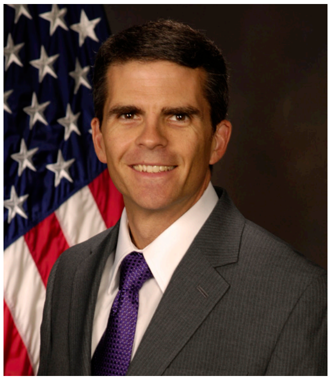
The new program curriculum is geared towards integrating physics based, Atmospheric Sciences to operational problems and is nearly ready for its start in the fall of 2016. AFIT's Atmospheric Science faculty is looking forward to a strong start of the new program, the opportunity to solve a broader range of significant operational research problems, and a continued strong relationship with Air Force Weather.

FACULTY
Highlights

Dr. Brett Borghetti
2015 AETC Winner and Nominee to AF Level Competition

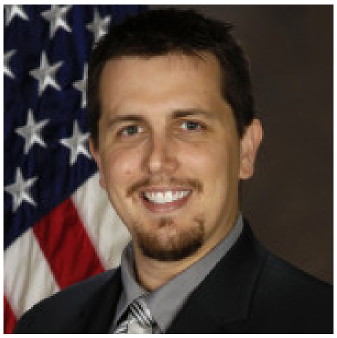
The annual USAF STEM awards honor the brightest minds in the Air Force. As the Air Education and Training Command nominee for the USAF Outstanding Science and Engineering Educator Award, Dr. Brett Borghetti was selected as AETC's top STEM educator for the 2014 calendar year.

Dr. Borghetti earned a Ph.D. in Computer Science in 2008 from the University of Minnesota, Twin Cities, MN; a M.S. degree in Computer Systems in 1996 from the Air Force Institute of Technology (AFIT) in Dayton, OH; and a B.S. in Electrical Engineering in 1992 from Worcester Polytechnic Institute (WPI), Worcester, MA. Brett is currently an Assistant Professor of Computer Science at AFIT. His research interests focus on improving human-machine team performance in complex environments using artificial intelligence and machine learning. He has research experience in human performance, statistical machine learning, genetic algorithms, self-organizing systems, neural networks, game theory, information theory and cognitive science.



Dr. Tony Kelly

2015 Junior Civilian Career Engineering Award



Dr. Tony D. Kelly joined AFIT in 2014 as a Research Assistant Professor of Nuclear Engineering in the Department of Engineering Physics. He obtained his doctorate in nuclear engineering from AFIT in 2013, having previously received a master's degree in particle physics at the University of Nebraska-Lincoln through research collaborations with CERN.

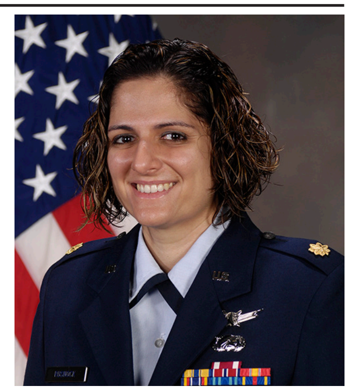
While at AFIT, Dr. Kelly pioneered novel research with frequent publications of actinide materials and radiation detection (amongst many other research fields and subfields). For his research, as well as modernizing AFIT courses and scope while advising his own students, he received the Junior Civilian Career Engineering Awards at the AFIT and AETC levels in 2015. Additionally, during his time at AFIT, Dr. Kelly demonstrated a commitment to local, national, and international communities through outreach efforts spanning from STEM activities to assisting nonprofits in resource diminished regions such as Lesotho in Africa. He was recognized for his community involvement by awarding him the Lt. Col Charles P. Brothers, Jr. Outstanding Volunteer Service Award.

Major Christina Rusnock

Engineering Economy Track Best Paper Award

Major Christina Rusnock, PhD, Assistant Processor, Department of Systems Engineering and Management, was awarded the Engineering Economy Track Best Paper by the Institute of Industrial Engineers at the 2015 Industrial and Systems Engineering Research Conference, for her research on predicting cost growth for military and civilian space systems.

Using forty years' worth of data from Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) space programs, her research sought to provide space systems cost estimators with a forecasting tool for space system cost growth by identifying factors contributing to growth, quantifying the relative impact of these factors, and establishing a set of models for predicting space system cost growth.



IN Memoriam

Dr. Charles Bridgman
Professor Emeritus of Nuclear Engineering

Sadly, 2015 marked the loss of one of AFIT's most prestigious faculty, Dr. Charles (Jim) Bridgman. Dr. Bridgman was a well respected authority on nuclear weapons effects and known throughout the entire nuclear enterprise. He is well known for his text, "Introduction to the Physics of Nuclear Weapon Effects", largely compiled from the class notes from his AFIT nuclear weapons effects courses. These courses continue to be a key component to the nuclear engineering program today.

Students, fortunate enough to have had Dr. Bridgman in class, treasured him for his direct teaching methods, which often challenged them to expand beyond the text and apply their minds to solving complex, real world problems. Students remarked on his ability to probe deep into the subject maters. One commented that "a single question could spark weeks worth of discussion and a lifetime of learning." Dr. Bridgman's research, likewise, made a substantial impact. Throughout his career, he chaired 115 MS students and 15 PhD students. Two of his students became general officers, four SES level executives and one an astronaut.

While at AFIT, Dr. Bridgman served as an Engineering Physics faculty member, the nuclear engineering program chairman and as the Associate Dean of Research. His work in this latter position established the methods to create the research programs that are vital to AFIT's graduate programs. In his later years, as a Professor Emeritus, he continued to enrich AFIT and the nuclear community as the primary subject matter expert in developing the Nuclear Weapons Policy and Proliferation Certification program. This program was developed to provide non-engineers with a comprehensive graduate education on nuclear weapons employment and effects, using distant learning. Dr. Bridman was initially reluctant to participate, but became substantially involved in supporting the program. He wrote two texts and recorded hundreds of hours of video lectures, helping to maintain his rich legacy as an educator. He is deeply missed.

Dr. Michael Haas
Associate Professor of Systems Engineering

Dr. Michael Haas, an Associate Professor of Systems Engineering in the Department of Systems Engineering and Management, died unexpectedly on Monday, December 15, 2014. Ever passionate about improving the utility of visual display systems, he was involved in early research on concepts that would become known as synthetic vision and virtual reality systems.

During his 30 year career with the Air Force as a research engineer with the Air Force Research Laboratory's 711th Human Performance Wing, he advanced and became known for his contributions to the development of the user interfaces in cockpit and simulation displays. Illustrating his breadth in electrical, as well as human factors engineering, he served as faculty in the Department of Electrical and Computer Engineering from 2009 to 2011 and joined the Department of Systems Engineering and Management in 2013.

Dr. Haas was a graduate of Wright State University (B.S.), the University of Utah (M.E.E.E.) and University of South Hampton, England (Ph.D.). He was married with one son, of whom he was very proud. Dr. Haas was the holder of three U.S. patents, and the editor of a book and two journal special issues. Additionally, he published 21 peer-reviewed journal articles, 12 books chapters, and 15 technical reports.

Dr. Haas was a licensed professional engineer, a senior member of the Institute of Electrical and Electronics Engineering and a member of the Association of Computing Machinery. Dr. Haas' experience, good nature and calm guidance are missed by many within AFIT and the 711th Human Performance Wing.

ALUMNI Highlights

Anne Chinnery
M.S. Aeronautical Engineering, 1993

Anne Chinnery earned her bachelor's degree from the Air Force Academy and her master's degree in aeronautical engineering from AFIT in 1993. "I specialized in rocket propulsion and space craft attitude dynamics. It was all very relevant to what I am doing today."

After earning her degree, Chinnery worked in the intelligence field before being assigned to Vandenberg AFB working on space launches. After leaving the AF in 1999, Chinnery worked for several small commercial aerospace companies that allowed her to be more hands on and delve into the technical topics that she loves.

Currently, Chinnery is a consultant with Firefly Space Systems. Firefly is a small satellite launch company located in Cedar Park, Texas, created to provide low-cost, high-performance space launch capabilities for the under-served small satellite market, where secondary-payload launches are often the only option.

Chinnery has thrived in the startup industry. "At a small company you get to do a lot of things. You aren't just sitting in a cubical designing a widget; you get to design the whole subsystem and see the entire process from design to manufacture, test and hopefully; see it fly. But you have to be motived because there is a ton of work. That can be challenging, but I think it is just so exciting!"

Regarding her time at AFIT, Chinnery says that "The AFIT program is wonderful. Providing the opportunity for military members to get their master's degree is very important and it really will help you in the rest of your life and career. I would say thank you to AFIT for the great education I received."

Chinnery's advice to current AFIT students is to challenge themselves. "Take classes that are hard, try the things that you aren't sure you can do because those are the things that will really teach you how to learn."

Jason Cook
M.S. Engineering Management, 2006, Distinguished Graduate

Jason Cook earned his master's degree from AFIT in engineering management in 2006. He is the Deputy Director for the 721st Civil Engineer Squadron at Cheyenne Mountain Air Force Station (CMAFS) in Colorado and was a member of the team who received the 2015 Federal Energy and Water Management Award. The team's efforts reduced energy consumption by 8.5% in FY 2014 as compared to the previous year and 18.4% from the FY 2003 baseline.

After earning his master's degree, Cook moved to AFIT's Civil Engineer School where had the opportunity to teach and guide new 2nd Lieutenants in the AF. After leaving the AF, Cook moved to CMAFS, where he eventually became the deputy director.

The most challenging part of his job is balancing the mission reliability with the standard civil engineer work load. It is the engineering challenges that keep Cook excited about his job and working at such a unique facility brings brand new challenges every month.

Cook states, "I have used the information that I learned from my courses at AFIT often, referring back to the techniques I learned and applying them to the problems in my current job. For example, I use Monte Carlo simulations in forecasting, statistics helps me interpret the information I receive on reliability for our systems, as well as availability modeling to provide professional engineer oversight on our facility's major systems."

Tyler Nielson
M.S. Engineering Management, 2007

Tyler Nielsen earned his master's degree from AFIT in engineering management in 2007. He currently works in facility management at the Utah Test and Training Range at Hill AFB, where he is responsible for the day to day activities of maintaining the facility as well as many special projects on the range. "It's a nice mix of engineering, planning, and future project development. But going out on the range and working on projects that directly support the warfighter is the most fun part of the day."

Nielsen was a member of the team who received the 2015 Federal Energy and Water Management Award. At the time of the award, Nielsen was the Operations Flight Chief for the 721st Civil Engineer Squadron at Cheyenne Mountain Air Force Station (CMAFS) in Colorado.

Nielsen is enthusiastic when discussing his time at AFIT. "AFIT was phenomenal! You don't often get an opportunity to really have the freedom to pursue your interests. The faculty I worked with allowed me to explore green design and look at a lot of really radical ideas for the Air Force. At AFIT we were talking about big ideas like the possibility of sod roofs, green walls, solar powered parking structures, and zero emission buildings. My time at AFIT really changed my perception of construction to not be limited by conventional thinking. It was some of the best years of my professional career."

Nielsen's advice for young civil engineering professionals is to be a jack-of-all-trades. "You may not have to be the expert, but you need to understand the fundamentals of engineering across the board and be able to speak intelligently about the issues. Know your electric, mechanical and civil engineering." As for current AFIT students, Nielsen says to have fun. "AFIT is awesome. Do research that interests you. Don't limit yourself – if you aren't having fun you are doing the wrong research – go figure out what you want to do."

UPCOMING Events

AFIT to Celebrate its 100th year!

What started as a school for select officers in 1919, has grown into a premier educational institution for: officer and enlisted students, international students, Department of Defense civilians, and members of all branches of the armed services. Here at AFIT, we continue to stress the values that we were founded on, excellence in education and research, to move AFIT through the twenty-first century, retaining its flexibility and resourcefulness in accomplishing its mission.

2019 will mark AFIT's 100th anniversary, and plans are underway for a celebration befitting such an occasion. If you would like more information about the plans, please contact the Alumni Affairs and Faculty Personnel Programs Manager, Ms. Kathleen Scott, at Kathleen.Scott@afit.edu.

RESEARCH
Data

Selected Large Awards for Fiscal Year 15

"Efficient Predictions of Excited States for Nanomaterials Using ACES III & IV"
$892K - United States Army Corps of Engineers
Principal Investigator: Dr. Larry Burggraf

"Test and Evaluation Center of Excellence"
$866K - Office of the Secretary of Defense
Principal Investigator: Dr. Darryl Ahner

"The Science of Test: Advanced Test and Evaluation in Support of the DOD Test and Evaluation Enterprise"
$400K - Office of the Secretary of Defense, Test Resource Management Center
Principal Investigator: Dr. Raymond Hill

"Rapid Location of Radiation Sources in Complex Environments Using Optical and Radiation Sensors"
$382.5K - Defense Threat Reduction Agency
Principal Investigator: Dr. David Bunker

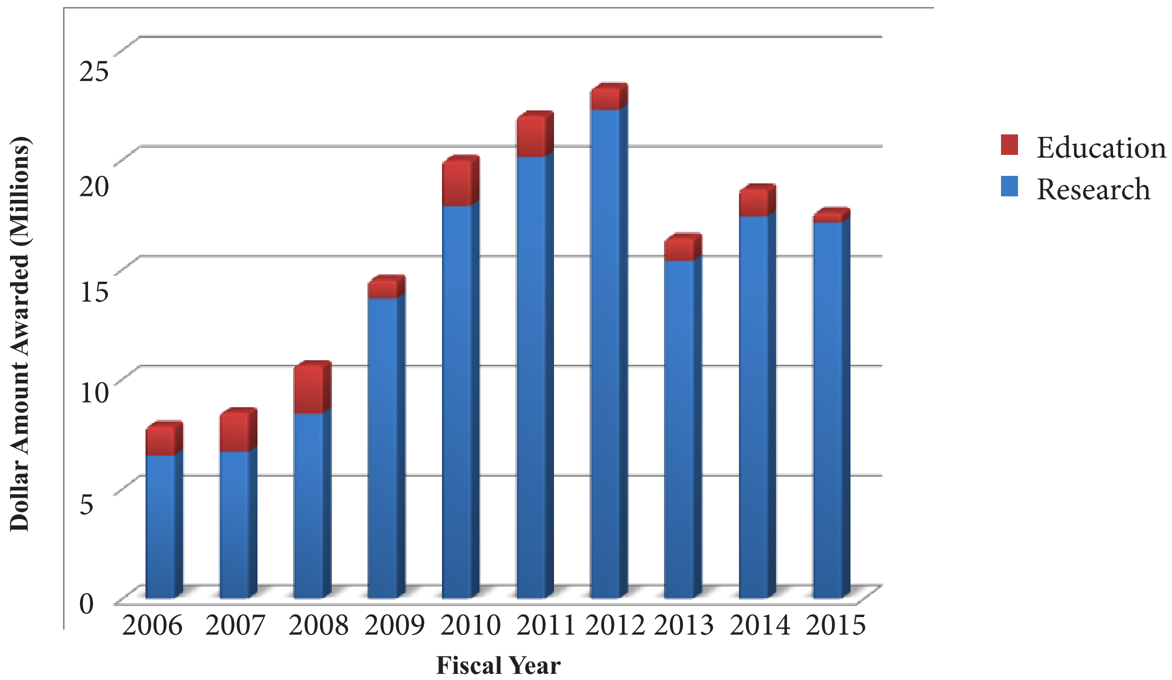
"CY2015 HELJTO AP TAWG Research and Analysis"
$370K - High Energy Laser Joint Technology Office
Principal Investigator: Dr. Steven Fiorino

"CY2015 HELJTO MS & TAWG Product Development"
$350K - High Energy Laser Joint Technology Office
Principal Investigator: Dr. Steven Fiorino

"Research, Analysis and Transition Support to the Directorate of Logistics and Sustainment Air Force Sustainment Center"
$350K - Air Force Materiel Command
Principal Investigator: Dr. Alan Johnson

"Polarimetric HSI for Improved Radioactive Source Detection Sensitivity and Localization Accuracy"
$327.4K - Defense Threat Reduction Agency
Principal Investigator: Dr. Kevin Gross

New Award History Fiscal Year 2005 - Fiscal Year 2015



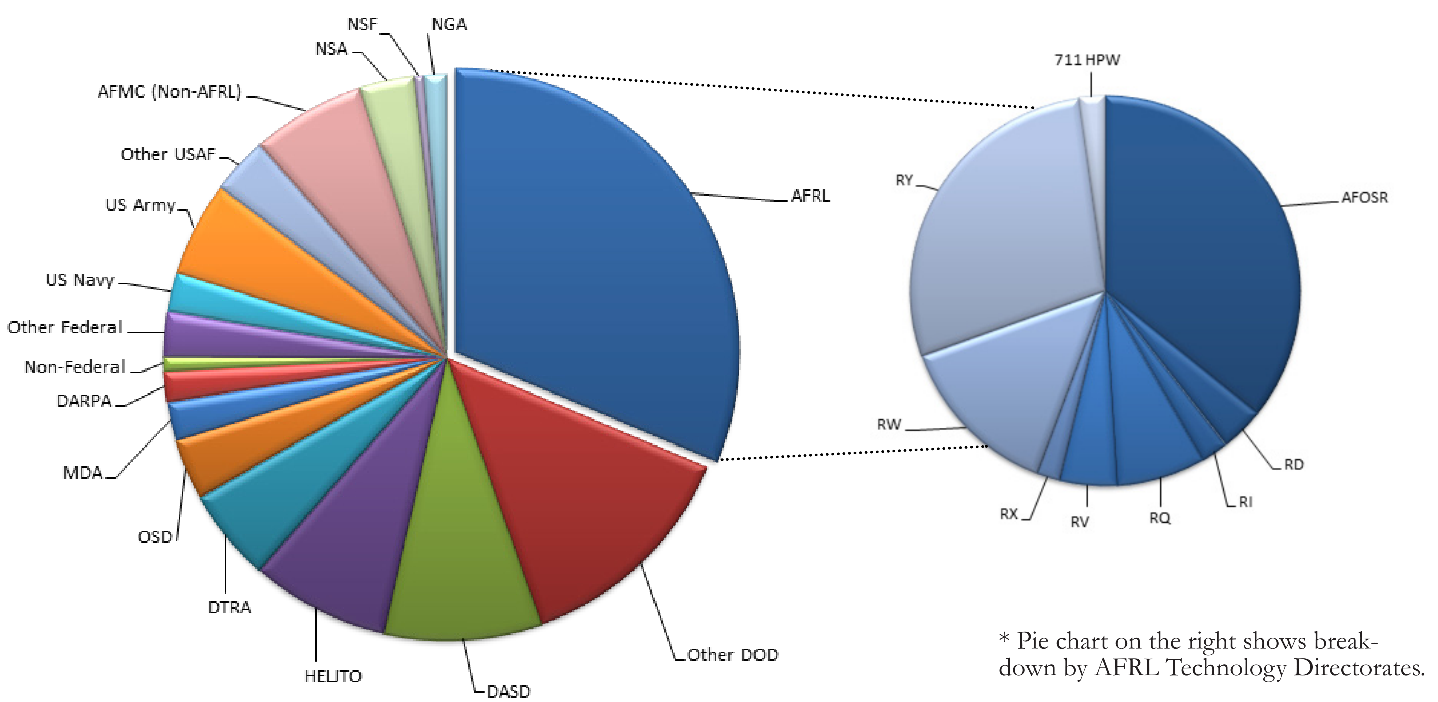
New FY15 Awards to Academic Departments and Research Centers

	Newly Awarded Research Projects		Newly Awarded Education Projects		Total FY15 Newly Awarded Projects		Total FY15 Research Expenditures
Departments	#	$k	#	$k	#	$k	$k
Mathematics & Statistics (ENC)	7	422	1	30	8	452	355
Electrical & Computer Eng (ENG)	63	4,828	2	204	65	5,032	5,153
Engineering Physics (ENP)	44	4,982	1	50	45	5,032	4,470
Research & Sponsored Programs (ENR)	1	377	-	-	1	377	-
Operational Sciences (ENS)	11	3,182	3	115	14	3,297	3,571
Systems Eng & Management (ENV)	11	717	1	8	12	725	837
Aeronautics & Astronautics (ENY)	48	2,622	2	49	51	2,671	2,552
TOTAL	**185**	**17,130**	**10**	**456**	**196**	**17,586**	**16,938**

Center	#	$k	#	$k	#	$k	$k
Autonomy and Navigation Technology (ANT)	25	2,174	-	-	25	2,174	2,599
Center for Cyberspace Research (CCR)	16	1,226	2	204	18	1,430	1,021
Center for Directed Energy	21	2,657	-	-	21	2,657	2,244
Center for Operational Analysis (COA)*	9	1,521	1	90	13	1,611	1,990
Center for Space Research and Assurance (CSRA)	15	1,310	-	-	15	1,310	1,287
Center for Tech Intel Studies & Research (CTISR)	12	1,445	1	50	13	1,495	1,200
TOTAL	**98**	**10,333**	**4**	**344**	**105**	**10,677**	**10,341**

Note: Total research expenditures reported include institutional cost sharing, which is not included in newly awarded projects. Numbers reported to the ASEE and NSF research expenditure surveys vary somewhat due to differences in definitions. All Center funds are also included in departmental funding.

Sponsors of Fiscal Year 2015 Projects



* Pie chart on the right shows breakdown by AFRL Technology Directorates.

Enrolling at AFIT for Graduate Studies

The Graduate School of Engineering and Management offers multiple graduate and doctoral degree opportunities that focus on high-quality graduate education and research. We serve the Air Force as its graduate institution of choice for engineering, applied sciences, and selected areas of management. The appeal for our distinct educational opportunities is widespread and attracts high-quality students from other US armed services, Government agencies both inside and outside the DOD, and international military students. Of particular note, under the National Defense Authorization Act for Fiscal Year 2011, the Graduate School may enroll defense industry employees seeking a defense-related master's or doctoral degree. Tuition will be waived for all Air Force military and Air Force civilians, who are not sponsored by the Air Force to enroll at AFIT on a space-available basis.

Our automated application system provides immediate application information to the Office of Admissions, and there is no application fee. Because of our highly-automated admission processes, the Office of Admissions usually renders an admission decision within 21 days.

Prospective students will join a robust and energetic student body focused on learning and research. The Engineering Accreditation Commission (EAC) and the Applied Science Accreditation Commission (ASAC) of ABET accredits our eligible engineering and applied science programs. Students usually finish their master's programs within two years and the doctoral programs within three years. Enrollment averages around 700 full- and part-time students with a student-to-faculty ratio of 5:1. In academic year 2013-2014, 330 master's and doctoral degrees were awarded to 261 AF officers, 5 AF enlisted, 22 sister services, 29 civilians, and 13 international military officers. Our campus consists of eight buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information, visit www.afit.edu/admissions.

AFIT Internship Opportunities

Internship opportunities are available for undergraduate and graduate science, technology, engineering, and mathematics (STEM) students through the Southwestern Ohio Council for Higher Education (SOCHE). Students have the opportunity to work at AFIT through the Summer Internship Program, the Student Research Program, or both. Students benefit both academically and financially by working in state-of-the-art laboratories with top professionals in their field. Additionally, they can use this experience for senior projects, cooperative education, and graduate research. AFIT receives the benefit of top students, who bring new energy and ideas to the research projects.

For additional information regarding AFIT internship opportunities visit www.socheintern.org.

AFIT Research Centers

Air Force Center for Cyberspace Technical Excellence Center for Cyberspace Research	www.afit.edu/CCR/	Dr. Robert Mills
Autonomy and Navigation Technology Center	www.afit.edu/ANT/	Dr. John Raquet
Center for Directed Energy	www.afit.edu/CDE/	Dr. Steven Fiorino
Center for Operational Analysis	www.afit.edu/COA/	Dr. Paul Hartman
Center for Space Research and Assurance	www.afit.edu/CSRA/	Dr. Eric Swenson
Center for Technical Intelligence Studies & Research	www.afit.edu/CTISR/	Dr. Kevin Gross
OSD Scientific Test and Analysis Techniques Center of Excellence	www.afit.edu/STAT/	Dr. Darryl Ahner

Sponsoring Thesis Topics

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